

YMP-LBNL TECHNICAL IMPLEMENTING PROCEDURE -1.0, R0

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**Magnetotelluric Measurements**

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**1.0 PURPOSE.**

The objective of this procedure is to obtain in-situ data on the electrical resistivity of the rock strata to depths of several tens of kilometers. The Earth is an electrical conductor, in which electric currents (telluric currents) are induced by time-varying magnetic fields. As a result of ionospheric and atmospheric electromagnetic disturbances, these fields continually surround the Earth. This procedure describes the measurements of these natural electromagnetic fields, known as magnetotelluric (MT) fields, by means of electrodes and magnetic induction sensors emplaced on the surface of the Earth. With this instrumentation, simultaneous measurements are made of the voltages (E) resulting from the telluric currents, and of the related magnetic fields (H). The phase and amplitude of the E/H ratios, as a function of frequency, are dependent on the electrical resistivity within the Earth. The distribution of electrical resistivity can reflect crustal conditions, and provides independent information supplemental to other geophysical and geological data used to infer crustal composition, structure, geologic history, and future geologic events that may affect radioactive waste storage. Electrical resistivity is especially useful in mapping subsurface features such as: 1) large volume, high-temperatures areas such as magma masses or geothermal reservoirs, 2) large fluid-filled zones having connected porosities, such as volcanic strata or fault-zones, 3) zones of altered, clay rich or serpentized rock, such as major fault zones, and 4) major masses of compact, unfractured, fresh igneous rock surrounded by contrasting strata.

- 1.1 Technical Requirements: Implementation of this procedure assists in meeting the technical requirements of Study Plan 8.3.1.4.2.1, Characterization of the Vertical and Lateral Distribution of Stratigraphic Units Within the Site Area.

**2.0 SCOPE.**

This procedure applies to YMP-LBNL personnel and their contractors who use this procedure to collect data for site characterization.

- 2.1 Impact on Other Work: The work done to this procedure does not physically or adversely impact other activities on the Project. There are no other YMP-LBNL technical procedures that interface with work done according to this procedure.

3.0 **PROCEDURE.** There are no special prerequisites required for the implementation of this procedure. Various instrumental and data acquisition related precautions are as noted within the body of the text (Para. 3.0, Methods).

- 3.1 Environmental Conditions: Station locations are specified by the PI or his delegate based on scientific objectives, accessibility, and cultural noise sources. Because natural and cultural obstacles and noise sources can affect data quality, the following environmental characteristics must be avoided or minimized by prudent selection of measurement locations:

- 1) Power sources and power lines produce 60-Hz electromagnetic fields and their harmonics, as well as broad-band signals associated with transient power surges, that contaminate the natural electromagnetic fields.

- 2) Stationary conductors such as pipelines and fences attract telluric currents and act as inductive media that distort the natural electromagnetic fields.
  - 3) Active byways with moving metallic vehicles produce magnetic fields that contaminate the natural fields.
- 3.2 Limitations. The procedure is limited by the constraints that must be observed in selecting measurement sites (see Para. 2.1), including location access constraints, which affect the distribution of stations, hence the spatial detail of interpreted resistivity. Electromagnetic noise sources that contaminate the data affect the quality of interpretation.

Limitations imposed by equipment include those of frequency and amplitude response. Depth of investigation depends on both earth conductivities and the lowest frequency that can be practically recorded. Resolution of the Earth's resistivity structure depends on the bandwidth and precision of individual estimates of the E/H parameters. Limitations in the signal quality are imposed when natural signal levels are low compared to instrumental or cultural noise sources.

Natural conditions unfavorable for data acquisition include the onset of severe thunderstorms, high winds, and temperatures beyond the operating range specified by the manufacturer of the electronic components. In such cases the station must be abandoned or repeated as determined by the PI or his delegate.

- 3.3 Materials/Equipment Required. There is no special handling or shipping required for the equipment. Measurement ranges and accuracies sufficient to attain the stated overall accuracy of data are as listed below. Detailed information on the equipment listed below and field set-up are as described in Para. 5.1, Instrumentation. All materials and equipment shall be as per listed manufacturer or equivalent.

- o Electric field sensors (electrodes grounded at the ends of two horizontal, orthogonal wires)
- o Insulated, conducting, wire
- o High-impedance multimeter (with a range of 10-100,000 ohm, an impedance of 10Mohm, and an accuracy of 10%)
- o Magnetic-field sensors (induction coils wound around high-magnetic permeability alloy cores (Stanley and Tinkler, 1982))
- o Preamplifiers (Stanley and Tinkler, 1982)
- o Insulated and shielded cables
- o Signal conditioning electronics (matched filter/amplifier system for each channel of data)
- o Signal source that provides variable amplitude signals over the frequency range of .001 to 100 Hz and accuracy of  $\pm 5\%$  relative dB (General Research, Dial-a-Source model 3325A, Hewlett Packard Spectrum Analyzer Model 3582A, Tektronix Dual Time Base Model 7853A, or equivalents)
- o Oscilloscope with a range of 0.001-100 Hz, and an accuracy of  $\pm 5\%$  relative dB (Tektronix model 466 or equivalent)
- o Commercial-grade 12 bit or better analog-to-digital (A/D) conversion unit

- 3.4 Software. Software used in this procedure is not Scientific and Engineering Software (SES) as described in YMP-LBNL-QIP SI.0,R0. Software used to perform data-acquisition is embedded in the instrumentation. Use of the instrumentation incorporates an internal self-check that demonstrates that the software is operating correctly.

- 3.5 Methods. The magnetotelluric method is one of several electrical geophysical methods providing information on the resistivity of the Earth (Keller and Frischknecht, 1966). The magnetotelluric

method is unique in using natural electromagnetic fields over a wide frequency range, typically 20 kHz down to 0.001 Hz. This makes it logistically independent of signal transmitters, and provides penetration in the Earth to several tens of kilometers.

The signals measured are complex, relatively low-amplitude, functions of time containing noise from various natural and cultural sources. Data acquisition techniques must account for these characteristics by careful site selection and the application of appropriate signal processing techniques as discussed in texts such as Bendat and Piersol (1971, chapter 9).

The method is based on electromagnetic induction in stationary conducting media. The governing equation appropriate to the frequencies used and the properties of the Earth is the diffusion equation. Fundamental principles are discussed in geophysical texts such as Keller and Frischknecht (1966, p. 197-250). Details of the application of the magnetotelluric method are discussed by Vozoff (1972).

Measurements are made by using a data-acquisition system and supporting electronics and sensors that are transportable by a motorized vehicle. Analog data acquired in the time domain are filtered, amplified, digitally sampled, converted into the frequency domain, and combined into parameters that reflect noise-conditions in the signal and electrical resistivity of the Earth.

**3.5.1 Instrumentation:** Electric field sensors consist of electrodes grounded at the ends of two horizontal, orthogonal wires. Each electrode is connected to the data acquisition electronics by insulated, conducting, wire. Configuration of the lines, including electrode separation distances and wire azimuths, are determined by the PI or his delegate appropriate with field conditions.

Electrodes may be non-polarizing types, such as lead in lead-chloride solution or copper in copper-sulfate, contained in a porous media that allows contact with the ground, or conducting metal, such as lead, copper, or silver (Keller and Frischknecht, 1966, p. 91-92; Petiau and Dupis, 1980). The electrodes and their cabling into data acquisition electronics should not generate appreciable noise signals and have sufficiently low contact resistance so as to not bias the voltage measurements. Electrode noise is largely determined by the electrochemistry between the electrode and ground. Contact resistance is largely determined by the local rock and soil conditions and electrode emplacements. Electric noise in the cabling may be caused by non-integrity of the insulation or by cable movements, such as caused by wind, in the Earth's magnetic field that induce voltages in the wire. Contact resistance may be checked by measurements between the electrodes using a high-impedance multimeter. Signal-to-noise characteristics may be checked by comparing time-domain traces of the electric fields to each other and to those of the magnetic field. The ratio of contact resistance to the input impedance of the data conditioning electronics should be less than about 0.005 (for 0.5% electric field precision).

The Earth's electric signal may have a DC component caused by cultural features, geologic conditions, or electrochemical reactions at the electrodes. Therefore, provision is made to switch in a DC voltage bias to the measured electric signal that will cancel the Earth's DC component and maintain a near-zero base level for the electric fluctuations that comprise the induced signal.

Magnetic-field sensors are induction coils wound around high-magnetic permeability alloy cores (Stanley and Tinkler, 1982). Two coils are placed horizontally on sand-bags or on soft soil in shallow depressions paralleling the E-sensors, and covered with non-metallic shields. The coil emplacements must stabilize the sensors against wind- and direct-sunlight-induced temperature variations. At low frequencies induction coils may have to be buried 1 to 2 feet deep.

Sensor signals are fed into preamplifiers (Stanley and Tinkler, 1982) and then transmitted to the signal conditioning electronics through insulated and shielded cables. Sensors are sufficiently isolated from other hardware so that magnetic and electric signals from this hardware is insignificant (less than about 1-percent) compared to the natural signals.

Signal conditioning electronics consist of matched filter and amplifier systems for each channel of data. Each channel includes a selectable low-pass filter, a band-rejection filter centered at 60 Hz and harmonics, a selectable high-pass filter and adjustable-gain amplifiers. The analog signal-conditioning parameters (low-pass frequencies, high-pass frequencies, and gains) are operator selectable to match ambient signal conditions with the dynamic range of the digital system and the required frequency content of the data.

The frequency range of the data acquisition electronics spans at least 100 to 0.001 Hz, with individual frequency bands spanning at least 1.2 decade and overlapping adjacent bands at least on the high and low-pass frequencies (3-dB attenuation-frequencies). The sample rate is selectable in the range of at least 20 to 0.25 Hz. The preamplifier plus amplifier system spans a gain range of at least  $(5 \text{ to } 1,000) \times 10^3$  for the E-fields and  $(1 \text{ to } 200) \times 10^4$  for the H-fields, selectable at intervals of at least 1/2 decade.

Conditioned signals are digitally sampled by a commercial-grade, analog-to-digital (A/D) conversion unit having at least 12-bit resolution, and stored in digital memory for further processing. There is a provision for observing the time-domain signals for the purpose of evaluating signal conditions and the operation of sensors and data conditioning electronics.

A commercial-grade, microprocessor-based, control system with monitoring and data storage devices performs the A/D conversion, the transformation of data from time-domain to frequency-domain, the magnetotelluric calculations and data storage functions. Final data storage is on magnetic tapes or disks or equivalent digital storage media.

**3.5.2 Data Acquisition:** The functions of the operators are to: (1) emplace the instruments, (2) set the data-acquisition variables, (3) record the data acquisition information, 4) control the data acquisition system, and (5) ensure that sufficient and adequate data have been acquired. An important part of function (5) is to evaluate the observed signals for noise and to modify the instrument emplacement, data-acquisition variables or site location as necessary.

Data are acquired over various frequency bands and with data-acquisition variables that are determined by the PI or his delegate. Data acquisition variables are recorded to allow subsequent evaluation of the sounding during interpretation. Station documentation is recorded as shown on Attachment 1, with supplemental sheets as necessary. Information required for each sounding includes: station identification, date of sounding, and for each frequency data set: time of acquisition, data-set name, software program used, number of samples, sample interval (DT), filter settings (band pass, low-pass, and high pass poles as applicable), and amplifier gains for each channel. In addition, station notes should include appropriate comments on station location, data appearance, probable noise sources, weather and terrain. The station location should be recorded on a map of scale 1:100,000, or less (1:62,500, 1:24,000) with an accuracy of at least 100m or with notes explaining why greater inaccuracies may be present. As part of data acquisition the operator must measure and record the azimuth of the E and H directions.

Natural electromagnetic fields may vary considerably in amplitude and noise characteristics over the time period required to acquire data for one frequency band. Therefore repeated observations are made for the required frequency bands to allow selection of higher quality data or to allow for ensemble averaging to improve data quality. Based on coherency, scatter, and consistency of the E/H data within and among the different frequency bands, the PI or his

delegate decides when data acquisition is sufficient and adequate (see Para. 9.0). There are times when a site will not yield acceptable data, as when natural or cultural disturbances are large (see Limitations, Para. 2.2). In such cases the station must be abandoned or repeated as determined by the PI or his delegate.

At the termination of data acquisition, the digital data and backup copies of the data are stored on stable, computer readable, media such as high-quality magnetic disks. Basic data resulting from data acquisition are cross- and auto-power spectra of the E and H fields.

**3.5.3 Data Processing:** Digital time-series are converted to frequency-domain, auto- and cross-spectral estimates, and combined into transfer functions that define the E/H relationships. Algorithms used are based on those discussed by Vozoff (1972) and Clark and others (1983).

Spectral-analysis procedures are based on time series of at least 128 samples in length. Time- and frequency-domain averaging parameters are determined by the PI or his delegate consistent with the required frequency bands. Spectral estimates should be at frequency intervals of 0.25 decade or smaller.

The final products are the tensor E/H transfer functions and their quality indicators resulting from the spectral processing. For each of the two sets of orthogonal E/H pairs rotated to principal axes these data include (Vozoff, 1972): frequency, apparent resistivity, phase, rotation angle, coherency, and skew.

**3.5.4 System Verification:** The procedure for verification of system response has two levels: (1) Laboratory verification of the induction coils and the amplifier/filter unit (Para. 5.4.1). This laboratory verification is required for any system component when it is constructed, modified, or repaired. (2) An abbreviated laboratory verification consisting only of the steps in Para. 5.4.1, Item 1), and field verification (Para. 5.4.2). This second level is required for each field survey. System components failing response verification shall be withdrawn from use until reworked or repaired.

**3.5.4.1 LABORATORY VERIFICATION:** The amplifier/filter unit is verified by applying known signals to the unit inputs and measuring the response at the outputs. The goal is to verify that all channels are equivalent. Inasmuch as MT utilizes ratios among components, it is not critical that each channel be verified in absolute values. In contrast, the preamplifiers and induction coil are verified in absolute values.

1. Verification of Matched Channels: A known signal source is connected to the sensor inputs, and the outputs that connect the A/D unit are used to monitor the response.

**A. Gain.**

- 1) Set the filters at constant values among all channels.
- 2) Apply a signal of known amplitude and frequency to the inputs and record the amplitudes at the outputs for all channels and all gain settings.
- 3) Amplitudes among channels should be equal within measurement accuracies and electronic tolerances of at least 3%.

**B. Frequency Response.**

- 1) Set the gains at constant values among all channels.

- 2) Choose and record the filter setting, including low-pass and band-pass poles.
- 3) Choose a reference channel from any of the available channels.
- 4) Apply a signal of known amplitude and frequency to the inputs and record the output signals from the test channels and the reference channel. Measurements are made for at least three frequencies in each of the frequency bands, including a frequency near the center of the band, and frequencies located near the -3-dB points on both the high-cut and low-cut ends of the bands.
- 5) Output amplitudes at the various frequencies for the test channels should be equal to that of the reference channel within the measurement accuracies and electronic tolerances of at least 3%.

## 2. Determination of the Frequency Response Functions:

- A. **Preamplifiers.** These units are designed for essentially constant gain across the bandwidth of data acquisition, hence the objective to verify the gain constants. The verification should be made at three frequencies spanning .01 to 10 Hz to verify that no significant (greater than 5%) frequency-dependent gain changes are present.

A signal of known frequency and amplitude is input to each of the amplifiers, and the output is measured. The ratio of output to input is calculated to determine the gain constant.

- B. **Amplifier/filter unit.** This procedure is applied to each of the frequency bands of the data-acquisition system. The procedure in Para. 5.4.1, Item 1), verifies that the different channels are matched, therefore only one channel need be verified for frequency response. The system is set up as in Para. 5.4.1, Item 1), then:

- 1) Choose and record the appropriate filter settings including low-pass and band-pass poles. The gain setting is arbitrary, but should be recorded.
- 2) Apply and record a set of signals at known frequency and amplitude to the input. Frequencies should cover the bandwidth of the filter settings with at least 3 frequencies/decade. Signal input parameters are recorded.
- 3) Record the output amplitudes. The results are presented as the ratio of output-to-input amplitude for each frequency.

- C. **Induction-coil.** The induction-coil response is verified using known signals produced by a fixed solenoid, in which the sensor coil is placed. The amplitude of the input signal is arbitrary. The response constants are the ratio of output to input, for at least 3 frequencies/decade across the data-acquisition frequency range (.001-100 Hz). Parameters controlling the input signal and the ratio computations are recorded. The resulting amplitude and phase response constants are recorded for each frequency.

3.5.4.2 FIELD VERIFICATION: This is a field data acquisition experiment at a test site where the geoelectric characteristics are known, such as the LBNL Davis Site, Jefferson County, Colorado, or a known site at Yucca Mountain. The objective is to acquire a sufficiently complete set of MT data to verify that the integrated system components and

software are operating as expected when compared to past recordings with qualified equipment and commercial MT systems.

System setup and data acquisition is performed as described in Paras. 5.1 and 5.2. Data are acquired at all frequency ranges to be used in the field survey. Evaluation consists of comparison of experiment results with previous data at the site. Inasmuch as there is no control over external conditions of signal strength and noise conditions, the evaluation is largely a qualitative judgment of the PI.

3.6 Calibration. Calibration is required for this procedure. Items that require calibration are:

- o The signal source that provides variable amplitude signals over the frequency range of .001 to 100 Hz (General Research, Dial-a-Source model 3325A, Hewlett Packard Spectrum Analyzer Model 3582A, Tektronix Dual Time Base Model 7853A, or equivalents).
- o The oscilloscope (Tektronix model 466 or equivalent).

These instruments are calibrated in accordance with YMP-LBNL-QIP-12.0, Documenting the Usage of Measuring and Test Equipment, by a YMP-LBNL approved supplier prior to use on the Yucca Mountain Project (YMP), every three years, and after the last YMP data has been collected. Calibrations shall meet or exceed the range and accuracies specified in Para. 3.0.

3.7 SAMPLES. Samples are not collected or handled as part of this procedure.

3.8 VERIFICATIONS and HOLD POINTS. None.

4.0 RECORDS MANAGEMENT. The magnetotelluric method has data-quality control parameters intrinsic to the method. These parameters are part of the acquired data and include coherency, skew, and estimated errors for each frequency-averaged estimate of the E/H tensor elements (Vozoff, 1972; Sims, Bostick and Smith, 1971; Clark and others, 1983). In addition, there is the property of "smoothness" of sounding curves. These parameters are described below with guidelines on their use. A combination of several undesirable data-quality indicators often suggests modification of the data acquisition parameters, or sounding location.

- 4.1 Coherency: This is a measure of the correlation between the E and H fields and predictability of the E fields from the H fields. Coherency less than about 0.8 generally indicates problems associated with local noise sources associated with instrumentation or cultural effects. It can also indicate localized natural sources such as lightning that do not conform to the MT assumption of spatially uniform source fields. Low coherency can also be associated with high skew, indicating that the fields are not coupled in the normal Ex-Hy, Ey-Hx modes.
- 4.2 Skew: This is a measure of the ratio of the amplitudes of the diagonal impedance elements to the off-diagonal impedance elements. Lower values, less than about 0.3, are desirable. However, skew may be largely a function of earth resistivity inhomogeneities that can be accounted for by appropriate modeling. Other causes of high skew are local noise sources, local cultural features, and inhomogeneous or polarized source fields.
- 4.3 Errors Associated With Frequency-Averaged E/H Estimates: These can take the form of root-mean-square errors, or confidence intervals based on assumptions about the statistical distribution of error. Generally, high errors, typically relative errors of 15-percent or more (or roughly equivalent to errors of 0.15 of a log cycle in apparent resistivity), are associated with low coherency. It is desirable to have data with 10-percent or less relative error.

- 4.4 Sounding Curve Smoothness: Well behaved MT curves will show smooth variations between estimated E/H elements. Sudden offsets, rapid changes in curvature such as slope reversals across less than 0.5 log cycle of frequency, and curve slopes greater than 45-degrees on log-frequency versus log-apparent resistivity are physically implausible. It is desirable to have low scatter, moderate curvature, and well-joined frequency-band curve segments.
- 4.5 Quality Assurance Records. Quality assurance records produced under this procedure and identified below will be prepared and submitted to the YMP-LBNL Record Processing Center in accordance with YMP-LBNL-QIP 17.0, Submitting Records to the YMP-LBNL Records Processing Center. These records shall be submitted by the Principal Investigator, or delegate, who is responsible for the work performed in accordance with this procedure. All records below are lifetime records.

4.5.1 DATA RECORDS: The fundamental information that is the object of this procedure is contained in two E/H response curves consisting of estimates of apparent resistivity and phase, along with data-quality parameters at various frequencies (f). The two curves represent the two, rotationally maximized, off-diagonal elements of the complex 2 x 2 E/H tensor, scaled to units of resistivity (R<sub>ij</sub>) and phase (P<sub>ij</sub>), (Vozoff, 1972; Sims, Bostick, and Smith, 1971). When units are in mV/km and nanoTesla (nT) for E<sub>i</sub> and H<sub>j</sub> respectively, the relationships for R<sub>ij</sub> in units of ohm-m and P<sub>ij</sub> (radians) are:

$$\begin{aligned} R_{xy} &= (0.2/f) |E_x/H_y|^2 & P_{xy} &= \arctan (\text{imag } E_x/\text{real } H_y) \\ R_{yx} &= (0.2/f) |E_y/H_x|^2 & P_{yx} &= \arctan (\text{imag } E_y/\text{real } H_x) \end{aligned}$$

where imag is the quadrature (out-of-phase) complex element and real is the in-phase complex element.

These parameters are used to interpret the electrical resistivity distribution of the Earth. Preliminary evaluations are accomplished by fitting the data to simple one-dimensional resistivity structures. Final interpretation of the distribution of resistivity is an office function which is not part of this technical procedure.

Data are documented on the Magnetotelluric Field Data Sheets (Attachment 1) or equivalent and on magnetic disks or other storage media. Collected data will be traceable to the instruments used to collect that data by notation on the field data sheets. These data shall be identified and tracked in accordance with YMP-LBNL-QIP SIII.3, Transferring Key Data to the Yucca Mountain Project Office. These data shall be reviewed per YMP-LBNL-QIP 6.1, Document Review, and submitted as part of a data records package in compliance with YMP-LBNL-QIP 17.0, Submitting Records to the YMP-LBNL Record Processing Center.

4.5.2 SUPPORTING INFORMATION: As appropriate, documentation containing supporting information shall be submitted as part of the data records package identified in Para. 10.1.

4.5.2.1 CALIBRATION RECORDS: The signal source and oscilloscope calibrations are documented by the YMP-LBNL approved supplier and are reviewed and maintained by the PI or delegate. Calibration documentation shall contain the information specified by YMP-LBNL-QIP 12.0.

## 5.0 RESPONSIBILITIES:



The Principal Investigator (PI) is responsible for assuring compliance with this procedure and will assure that users of this procedure have a minimum of three years experience in field acquisition of electric geophysical data or equivalent training subject to approval by the PI. Other responsibilities are described in YMP-LBNL-QIP 5.1, Preparing TIPS – Technical Implementing Procedures.

## 6.0 ACRONYMS AND DEFINITIONS. None.

## 7.0 REFERENCES.

References, if required as part of the implementation of this procedure, shall be made available for use at the work location.

Bendat, J. S., and Piersol, A. G., 1971, Random data: Analysis and measurement procedures. New York, Wiley-Interscience, 407 p.

Clarke, J., Gamble, T.D., Goubau, W.M., Koch, R.H., and Miracky, R.F., 1983, Remote-reference magnetotellurics: equipment and procedures: Geophysical Prospecting, v. 31, no. 1, p. 149-170.

Keller, G. V., and Frischknecht, F. C., 1966, Electrical methods in geophysical prospecting. New York, Pergamon Press, 519 p.

Petiau, G., and Dupis, A., 1980, Noise, temperature coefficient and long time stability of electrodes for telluric observations. Geophysical Prospecting, vol. 28, p. 792-804.

Sims, W. E., Bostick, F. X., Jr., and Smith, H. W., 1971, The estimation of magnetotelluric impedance tensor elements from measured data. Geophysics, vol. 36, No. 5, p. 938-942.

Stanley and Tinkler, 1982, A practical low-noise coil system for magnetotellurics. U.S. Geological Survey Open-File Report 83-85, 49 p., plus Appendix.

Vozoff, Keeva, 1972, The magnetotelluric method in the exploration of sedimentary basins. Geophysics, vol. 37, No. 1, p. 98-141.

YMP-LBNL-QIP SI.0, General Software Quality Assurance.

YMP-LBNL-QIP 6.1, Document Review.

YMP-LBNL-QIP 5.1, Preparing TIPS – Technical Implementing Procedures.

YMP-LBNL-QIP 12.0, Documenting the Usage of Measuring and Test Equipment.

YMP-LBNL-QIP 17.0, Submitting Records to the YMP-LBNL Record Processing Center.

Study Plan 8.3.1.4.1.2, Characterization of the Vertical and Lateral Distribution of Stratigraphic Units within the Site Area.

## 8.0 ATTACHMENTS.

Attachment 1: Magnetotelluric Field Data Sheet

## 9.0 REVISION HISTORY:

None

10.0 REVIEW AND APPROVALS

EFFECTIVE DATE:

_____ Preparer	_____ Date	_____ Principal Investigator	_____ Date
_____ Technical Reviewer	_____ Date	_____ YMP-LBNL QA Manager	_____ Date
_____ QA Reviewer	_____ Date	_____ YMP-LBNL Project Manager	_____ Date

# MAGNETOTELLURIC FIELD DATA SHEET

Station: \_\_\_\_\_

Date: \_\_\_\_\_

[illegible]**STATION NOTES:**

**IDENTIFICATION OF EQUIPMENT USED TO COLLECT THIS DATA (model and serial number):**

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